PATENT ABSTRACTS OF JAPAN

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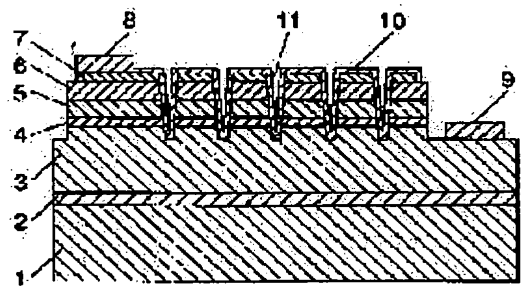
(54) GALLIUM NITRIDE COMPOUND SEMICONDUCTOR LIGHT-EMITTING ELEMENT AND ITS MANUFACTURE

(57)Abstract:
PROBLEM TO BE SOLVED: To improve efficiency of light-emission by making a surface on which a light-transmitting electrode is formed a main-light-taking-out surface side.
SOLUTION: A board 1 is overlaid with a buffer layer 2, an n-type contact layer 3, a light-emitting layer 4, a p-type clad layer 5 and a p-type contact layer 6, which are comprised of gallium nitride compound semiconductor, in this order, and further the p-type contact layer 6 is overlaid with a light- transmitting electrode 7, and the light-transmitting electrode 7 is overlaid with a p-side electrode 8, and the n-type contact layer 3 with an n-side electrode 9, in this way a gallium nitride compound semiconductor light-emitting element is constituted. In this element, a plurality of recessed parts 11 are formed on the p-type contact layer 6 depressed from the light-transmitting electrode 7 side. Thereby the light that is emitted from the light-emitting layer 4 and propagated in a lateral direction in the light-emitting element is easy to take out from the recessed part 11 to the outside of the light-emitting element, and efficiency of light-emission is improved on the whole.



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CLAIMS

[Claim(s)]
[Claim 1] A gallium nitride system compound semiconductor light emitting device which the laminating of the first conductivity-type contact layer, a luminous layer, and the second conductivity-type contact layer which consist of a gallium nitride system compound semiconductor is carried out, and is a gallium nitride system compound semiconductor light emitting device by which a light transmission nature electrode is further formed on said second conductivity-type contact layer, and is characterized by forming two or more crevices which become depressed from said light transmission nature electrode side in said second conductivity-type contact layer.
[Claim 2] Said crevice is a gallium nitride system compound semiconductor light emitting device according to claim 1 characterized by being formed by Fukashi who reaches said luminous layer.
[Claim 3] A gallium nitride system compound semiconductor light emitting device according to claim 1 or 2 to which an inside of said crevice is characterized by being covered with an insulating film.
[Claim 4] A manufacture method of a gallium nitride system compound semiconductor light emitting device characterized by providing the following A production process into which the first conductivity-type contact layer and a luminous layer which consist of a gallium nitride system compound semiconductor, and the second conductivity-type contact layer are grown up A production process which forms a light transmission nature electrode on said second conductivity-type contact layer A production process which forms a mask in which a pattern which has a opening for forming a crevice which becomes depressed from said light transmission nature electrode side in said second conductivity-type contact layer was formed, on said light transmission nature electrode A production process which etches to the depth which reaches said luminous layer from said second conductivity-type contact layer side using said mask
[Claim 5] The production process which performs said etching is the manufacture method of the gallium-nitride system compound semiconductor light emitting device characterized by to carry out at the same production process as the production process at which the surface of said first conductivity-type contact layer exposes including the production process which forms the mask characterized by to provide the following formed a pattern, on said light-transmission nature electrode, and the production process which etch to the depth which reaches said luminous layer from said second conductivity-type contact layer side using said mask. A production process into which the first conductivity-type contact layer and a luminous layer which consist of a gallium nitride system compound semiconductor, and the second conductivity-type contact layer are grown up A production process at which the surface of said first conductivity-type contact layer is exposed A production process which is the manufacture method of a gallium nitride system compound semiconductor light emitting device including a production process which forms an electrode on this exposed first conductivity-type contact layer, and forms a light transmission nature electrode on said second conductivity-type contact layer further A opening for forming a crevice which becomes depressed from said light transmission nature electrode side in said second conductivity-type contact layer

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[The technical field to which invention belongs] This invention relates to the gallium nitride system compound semiconductor light emitting device used for optical devices, such as a light emitting diode, and its manufacture method.
[0002]
[Description of the Prior Art] The gallium nitride system compound semiconductor is used abundantly as a semiconductor material for a light luminescence device or elevated-temperature actuation electron devices, and blue, utilization in the field of green light emitting diode, and expansion in the field of the laser diode of a purple-blue color are progressing.
[0003] In manufacture of the light emitting device using this gallium nitride system compound semiconductor, it is in use in these days to grow up a gallium nitride system semiconductor thin film crystal by metal-organic chemical vapor deposition. This method in the coil which installed the substrate which consists of sapphire as a gallium nitride system semiconductor, SiC, GaN, etc. As material gas of 3 group element, organometallic compound gas (trimethylgallium ("TMG" is called hereafter), trimethylaluminum ("TMA" is called hereafter), trimethylindium ("TMI" is called hereafter), etc.), Ammonia, a hydrazine, etc. are supplied as material gas of 5 group element, substrate temperature is held at an about 700 degrees C - 1100 degrees C elevated temperature, n type layer, a luminous layer, and p type layer are grown up on a substrate, and laminating formation of these is carried out. At the time of growth of n type layer, it considers as n mold impurity material gas, and bis(cyclopentadienyl) magnesium (Cp2Mg) etc. grows up a mono silane (SiH4), germane (GeH4), etc. into the material gas and coincidence of 3 group element with a sink as p mold impurity material gas at the time of growth of p type layer.
[0004] A light emitting device can be obtained by forming n lateral electrode and p lateral electrode in the surface of n type layer, and the surface of p type layer after this growth formation, respectively, and dissociating in the shape of a chip. And it is made to complete as light emitting diode by fixing these light emitting devices to a leadframe etc., and finally closing with an epoxy resin etc.
[0005] In the latest gallium nitride system compound semiconductor light emitting device On the surface of n type layer which removed a part of p type layer, luminous layer, and n type layer from the surface of p type layer by etching, and was exposed, n lateral electrode The element structure which forms in the surface of p type layer the light transmission nature electrode of closing in which is the degree which can penetrate the light from a luminous layer as a p lateral electrode, respectively, and makes this light transmission nature electrode side the main light ejection side side is in use. Element size can be made small while according to such a configuration it can also set when preparing p lateral electrode and n lateral electrode in the same side side of an element, and being able to prevent the short circuit between p lateral electrode and n lateral electrode.
[0006] However, in the element structure to which the laminating of the gallium nitride system compound semiconductor was carried out, there are the following problems on silicon on sapphire as mentioned above. That is, there is a problem that the multiple echo of the

luminescence of a gallium nitride system compound semiconductor is carried out to the difference in the refractive index of the substrate for crystal growth and a gallium nitride system compound semiconductor and a gallium nitride system compound semiconductor light emitting device by those interfaces by the difference in a refractive index with the resin which closes it, and it cannot interfere, or the reflected light is absorbed inside a gallium nitride system compound semiconductor, and cannot take out luminescence outside efficiently.

[0007] The gallium nitride system compound semiconductor light emitting device characterized by making the surface of the maximum upper layer of said gallium nitride system compound semiconductor into a non-mirror plane in JP,6-291368,A as what solves such a problem in the light emitting device which comes to carry out the laminating of the gallium nitride system compound semiconductor on silicon on sapphire is proposed. Since the light reflected by the interface of silicon on sapphire and a gallium nitride system compound semiconductor layer is scattered about in the maximum upper layer made into the non-mirror plane according to this light emitting device, the multiple echo inside a gallium nitride system compound semiconductor is controlled, interference of light decreases and it is supposed that luminous efficiency will improve.

[0008]

[Problem(s) to be Solved by the Invention] However, there are the following problems also in the configuration which makes the maximum upper layer of a gallium nitride system compound semiconductor a non-mirror plane as mentioned above. Namely, although the light transmission nature electrode of closing in to the degree which makes the light from a luminous layer penetrate will be formed on this maximum upper layer when making this maximum upper layer side into the main light ejection side side of a light emitting device It cannot become very difficult to form an electrode ultra-thin in the maximum upper layer of a non-mirror plane in thickness homogeneity, and it cannot supply current to a gallium nitride system compound semiconductor from the electrode concerned at homogeneity, but has the problem of becoming the cause of reducing luminous efficiency on the contrary.

[0009] The technical problem which should be solved in this invention is offering the gallium nitride system compound semiconductor light emitting device which made the field the light transmission nature electrode's having been formed the main light ejection side side, and raised luminous efficiency, and its manufacture method.

[0010]

[Means for Solving the Problem] A gallium nitride system compound semiconductor light emitting device of this invention is characterized by forming two or more crevices which become depressed from a light transmission nature electrode side in a contact layer in which a light transmission nature electrode is formed.

[0011] According to such a configuration, it is emitted from a luminous layer and, as for the exterior of a light emitting device, light which spreads the interior of a light emitting device in the direction (longitudinal direction) parallel to a contact layer becomes is easy to be taken out from a crevice. That is, ejection effectiveness of light from a luminous layer is improved, and it becomes possible to raise luminous efficiency as a whole.

[0012] Moreover, a manufacture method of a gallium nitride system compound semiconductor light emitting device of this invention is characterized by performing formation of a crevice at the same production process as a production process of etching for exposing the first conductivity-type contact layer.

[0013] Since crevice formation can be performed simple according to such a manufacture method, without newly adding a production process for crevice formation, a manufacture method of a gallium nitride system compound semiconductor light emitting device which can raise luminous efficiency only by minute production process modification called modification of a mask pattern can be offered.

[0014]

[Embodiment of the Invention] The laminating of the first conductivity-type contact layer, luminous layer, and the second conductivity-type contact layer which consist of a gallium nitride system compound semiconductor is carried out, and invention according to claim 1 is a gallium

nitride system compound semiconductor light emitting device by which a light transmission nature electrode is further formed on said second conductivity-type contact layer, and is taken as the gallium nitride system compound semiconductor light emitting device characterized by forming two or more crevices which become depressed from said light transmission nature electrode side in said second conductivity-type contact layer. Thereby, it is emitted from a luminous layer and the light which spreads the interior of a light emitting device in a longitudinal direction becomes that it is easy to be taken out from a crevice in the light emitting device exterior. That is, the ejection effectiveness of the light to the light emitting device exterior is improvable.

[0015] Invention according to claim 2 uses said crevice as the gallium nitride system compound semiconductor light emitting device according to claim 1 characterized by being formed by Fukashi who reaches said luminous layer. Since this is easy to spread the light of the light emitting device made into double hetero structure focusing on a luminous layer with a comparatively small refractive index, light can be taken out more efficiently than the crevice formed to the depth which reaches the luminous layer, and the ejection effectiveness of the light to the light emitting device exterior can be raised more.

[0016] Invention according to claim 3 is taken as the gallium nitride system compound semiconductor light emitting device according to claim 1 or 2 to which the inside of said crevice is characterized by being covered with an insulating film. By minding such an insulating film, the difference between the refractive index of a nitride gallium system compound semiconductor and a refractive index with the resin which closes this can be eased, and the optical ejection effectiveness to the light emitting device exterior can be raised further. Moreover, when the crevice is formed over the second conductivity-type contact layer from the first conductivity-type contact layer, these short circuits can be prevented.

[0017] The production process into which the first conductivity-type contact layer and luminous layer which invention according to claim 4 becomes from a gallium nitride system compound semiconductor, and the second conductivity-type contact layer are grown up, The production process which forms the mask in which the pattern which has a opening for forming the production process which forms a light transmission nature electrode on said second conductivity-type contact layer, and the crevice which becomes depressed from said light transmission nature electrode side in said second conductivity-type contact layer was formed, on said light transmission nature electrode, It considers as the manufacture method of a gallium nitride system compound semiconductor light emitting device including the production process which etches to the depth which reaches said luminous layer from said second conductivity-type contact layer side using said mask. Thereby, the short circuit of the first conductivity-type contact layer and the second conductivity-type contact layer by the invasion of an electrode material to a crevice in a light transmission nature electrode formation production process can be prevented, and formation of the light transmission nature electrode which has a hole corresponding to a crevice can be simplified.

[0018] The production process into which the first conductivity-type contact layer and luminous layer which invention according to claim 5 becomes from a gallium nitride system compound semiconductor, and the second conductivity-type contact layer are grown up, It is the manufacture method of a gallium nitride system compound semiconductor light emitting device including the production process at which the surface of said first conductivity-type contact layer is exposed, and the production process which forms an electrode on this exposed first conductivity-type contact layer. Furthermore, the production process which forms a light transmission nature electrode on said second conductivity-type contact layer, The production process which forms the mask in which the pattern which has a opening for forming the crevice which becomes depressed from said light transmission nature electrode side in said second conductivity-type contact layer was formed, on said light transmission nature electrode, The production process which performs said etching including the production process which etches to the depth which reaches said luminous layer from said second conductivity-type contact layer side using said mask It considers as the manufacture method of the gallium nitride system compound semiconductor light emitting device characterized by carrying out at the same

production process as the production process at which the surface of said first conductivity-type contact layer is exposed. It can carry out simple, without adding a new production process for crevice formation by performing formation of a crevice at the same production process as the production process of etching for exposing the first conductivity-type contact layer.
[0019] Hereafter, the gestalt of operation of this invention is explained, referring to a drawing.
[0020] Drawing 1 is the drawing of longitudinal section showing the structure of the gallium nitride system compound semiconductor light emitting device concerning the gestalt of 1 operation of this invention.
[0021] In drawing 1 , a gallium nitride system compound semiconductor light emitting device is the structure where the laminating of a buffer layer 2, n mold contact layer 3 which consists of GaN, the luminous layer 4 which consists of InGaN, p mold cladding layer 5 which consists of AlGaN, and the p mold contact layer 6 which consists of GaN was carried out to order on the substrate 1 which consists of sapphire. In addition, in the gestalt of this operation, the first conductivity type and p mold are used as the second conductivity type for n mold.
[0022] furthermore, p mold contact layer 6 top -- the light transmission nature electrode 7 is mostly formed in the whole surface, and the p lateral electrode 8 for wirebonding is formed on the light transmission nature electrode 7. On the other hand, the n lateral electrode 9 is formed in the surface of n mold contact layer 3 exposed by etching by Fukashi who reaches n mold contact layer 3 from the surface of p mold contact layer 6.
[0023] And two or more crevices 11 which become depressed toward a luminous layer 4 from the light transmission nature electrode 7 side are formed in p mold contact layer 6. This crevice 11 pierces through the light transmission nature electrode 7, and is formed by Fukashi who reaches n mold contact layer 3 from p mold contact layer 6. Furthermore, the inside of a crevice 11 and the surface of the light transmission nature electrode 7 are covered with the insulating membrane formation 10.
[0024] In the gallium nitride system compound semiconductor light emitting device of the above-mentioned configuration, to the p lateral electrode 8, if negative voltage is impressed to the n lateral electrode 9, respectively, positive voltage From n mold contact layer 3 in which the electron hole used n mold cladding layer also [layer], and was formed from p mold cladding layer 5, an electron is poured into a luminous layer 4 through p mold contact layer 6, respectively. The light which has the energy corresponding to the band gap of a luminous layer 4 by the recombination of these electron holes and electrons is emitted from a luminous layer 4.
[0025] Although the light which goes upwards among the light emitted from the luminous layer 4 is taken out through the light transmission nature electrode 7 in the light emitting device exterior when it is the conventional light emitting device structure where the crevice 11 is not formed After decreasing a part of [other] light by absorption to the p mold cladding layer 5 and p mold contact layer 6 interior which spreads the interior of a light emitting device to a longitudinal direction, and consists of a gallium nitride system compound semiconductor etc., they will be taken out from the side of a light emitting device in the light emitting device exterior.
[0026] On the other hand, since attenuation by the absorption at the time of light spreading the interior of a light emitting device etc. is reduced while the light spread to a longitudinal direction among the light emitted from a luminous layer 4 becomes that it is easy to be taken out from a crevice 11 in the light emitting device exterior in the case of the light emitting device structure in the gestalt of this operation, the optical ejection effectiveness to the light emitting device exterior can be raised as a whole. Furthermore, by covering the inside of a crevice 11 with the insulating film 10 which has a refractive index between the refractive index of a gallium nitride system compound semiconductor, and the refractive index of the closure resin which closes this, or a closure ambient atmosphere, the difference between the refractive index of a gallium nitride system compound semiconductor and a refractive index with the resin which closes this is eased, and it becomes possible to raise further the optical ejection effectiveness to the light emitting device exterior.
[0027] Moreover, it enables it to take out a crevice 11 from the whole contact layer in which the crevice 11 was formed in the light which spreads the interior of a light emitting device in a longitudinal direction as the depth which reaches n mold contact layer 3 from p mold contact

layer 6. In addition, what is necessary is just to let it be the degree reaching, immediately near 5, for example, p mold cladding layer, of a luminous layer 4, although the depth of this crevice 11 does not necessarily need to reach the degree 4 from which the light which spreads the interior of a light emitting device to a longitudinal direction is taken out by reaching, i.e., a luminous layer.

[0028] As for especially the depth of this crevice 11, it is more desirable to consider as the depth which reaches a luminous layer 4. For example, it is because it becomes possible to take out light more efficiently than a crevice 11 when it considers as the depth of the degree which is easy to spread light focusing on the luminous layer 4 with a comparatively small refractive index, and reaches the luminous layer 4 when inserting the luminous layer 4 which consists of InGaN by n mold contact layer 3 which consists of high GaN and high AlGaN of a refractive index, and p mold cladding layer 5 and making it into double hetero structure like [this] the gestalt of this operation.

[0029] Furthermore, it is desirable to form a taper so that it may become thin as the medial surface of a crevice 11 progresses in the depth direction (direction which goes to a luminous layer 4 side from the light transmission nature electrode 7 side). While the light which carried out outgoing radiation from the side of a crevice 11 reflects in the side wall of the crevice 11 with this taper by this, it is led to the crevice 11 upper part, and it becomes that it is easy to be taken out in the light emitting device exterior.

[0030] Here, drawing 2 is the plan of the gallium nitride system compound semiconductor light emitting device shown in drawing 1 . As shown in drawing 2 , two or more crevices 11 are formed in the field of the light transmission nature electrode 7 of p mold contact layer 6 mostly formed in the whole surface.

[0031] the current poured into the p lateral electrode 8 from the p lateral electrode 8 in positive voltage at it when negative voltage was impressed to the n lateral electrode 9, respectively -- the light transmission nature electrode 7 -- it is mostly poured into the whole through breadth and p mold contact layer 6 to a luminous layer 4. The light emitted from the lower part of the light transmission nature electrode 7 among the light from the luminous layer 4 emitted by this is taken out through the light transmission nature electrode 7 in the light emitting device exterior, and in case the part passes the light transmission nature electrode 7, it is absorbed in part and decreased. On the other hand, since the light transmission nature electrode 7 does not exist in the field in which the crevice 11 was formed, the light taken out from a crevice 11 in the light emitting device exterior is taken out, without not being absorbed with the light transmission nature electrode 7, and decreasing.

[0032] Although the magnitude of the opening of a crevice 11 is based also on the number which forms a crevice 11, since the area of the light transmission nature electrode 7 will become small in connection with it if a opening is enlarged, the current density poured in to a luminous layer 4 becomes high. On the other hand, since formation of a opening will become difficult if a opening is made small, it is hard coming to control the depth of a crevice 11. Therefore, although a suitable range exists in the magnitude and the number of the openings of a crevice 11 When light emitting device size is set to abbreviation 350micrometerx350micrometer according to this invention persons' knowledge, Magnitude of the opening of a crevice 11 is made into the range of 0.5micrometerphi to 5 micrometerphi, and when adjusting the number of a crevice 11 so that the gross area may serve as 0.1 to 50% of range of the area of the light transmission nature electrode 7, improvement in optical ejection effectiveness is accepted notably.

[0033] Next, it explains, referring to a drawing about the manufacturing process of the gallium nitride system compound semiconductor light emitting device concerning the gestalt of this operation.

[0034] Drawing 3 to drawing 5 is the drawing of longitudinal section showing the manufacturing process of the gallium nitride system compound semiconductor element shown in drawing 1 . In addition, in the gestalt of this operation, although the manufacturing process in the element condition divided in the shape of a chip is explained, in an actual manufacturing process, each production process is carried out in the state of the wafer with which the light emitting device shown in a drawing was arranged two-dimensional.

[0035] As shown in drawing 3 , after first preparing the wafer into which the buffer layer 2 and n mold contact layer 3 which consist of a gallium nitride system compound semiconductor by metal-organic chemical vapor deposition, the luminous layer 4, p mold cladding layer 5, and p mold contact layer 6 were grown up in order on the substrate 1 which consists of sapphire, the light transmission nature electrode 7 is formed on p mold contact layer 6 using vacuum deposition and the photolithography method.
[0036] Next, the insulator layer 21 which consists of SiO2 with a heat CVD method is made to deposit on the light transmission nature electrode 7 and exposed p mold contact layer 6, as shown in drawing 4 . Furthermore, the photolithography method is used for this insulator layer 21, the space 13 for exposing a part of two or more hole 12 for forming two or more crevices 11 in the light transmission nature electrode 7 and surface of n mold contact layer 3 is formed, and it considers as the mask for the next etching.
[0037] Using this mask, by etching until it reaches n mold contact layer 3 from the surface side of exposed p mold contact layer 6, as shown in drawing 5 , while exposing the surface of n mold contact layer 3, by reactive ion etching etc., a crevice 11 is formed to the depth which reaches n mold contact layer 3 from the hole 12 formed on the light transmission nature electrode 7.
[0038] Then, etching is made to remove a part of insulator layer 21 on the light transmission nature electrode 7, and the p lateral electrode 8 and the n lateral electrode 9 are formed by vacuum deposition and the photolithography method, respectively on the surface of the exposed light transmission nature electrode 7, and the surface of exposed n mold contact layer 3. Furthermore, the insulating film 10 which consists of SiO2 grade which covers the inside of the light transmission nature electrode 7 and a crevice 11 with a heat CVD method and the photolithography method is formed. And the gallium nitride system compound light emitting device shown in drawing 1 is obtained by dissociating in the shape of a chip by dicing or the scribe.
[0039]
[Example] Hereafter, it explains, referring to a drawing about the example of the manufacture method of the gallium nitride system compound semiconductor light emitting device of this invention. In the following examples, although metal-organic chemical vapor deposition is used as the growth method of a gallium nitride system compound semiconductor, it is also possible for the growth method not to be limited to this and to use a molecular beam epitaxy method, an organic metal molecular beam epitaxy method, etc.
[0040] (Example) After laying first the substrate 1 of the sapphire with which the mirror plane was made to the surface in the substrate electrode holder in a coil, dirt and moisture, such as the organic substance which has adhered hydrogen gas to the surface of a substrate 1 by heating a substrate with a sink, were removed by keeping the skin temperature of a substrate 1 at 1000 degrees C for 10 minutes.
[0041] Next, the skin temperature of a substrate 1 was dropped even at 550 degrees C, and the buffer layer 2 which consists the nitrogen gas as main carrier gas, ammonia, and the carrier gas containing TMA for TMA of AlN with a sink was grown up by the thickness of 25nm.
[0042] Then, after stopping the carrier gas of TMA and carrying out a temperature up to 1050 degrees C, the carrier gas for TMG which newly contains TMG for the nitrogen gas and hydrogen gas as main carrier gas with a sink, and SiH4 gas were passed, and n mold contact layer 3 which consists of GaN which doped Si was grown up by the thickness of 2 micrometers.
[0043] After growing up n mold contact layer 3, the carrier gas for TMG and SiH4 gas were stopped, substrate 1 temperature was dropped even at 750 degrees C, and the luminous layer 4 of the single quantum well structure which consists a sink, and the carrier gas for TMG and the carrier gas containing TMI for TMI of In0.2Ga0.8N of undoping with a sink in the nitrogen gas as main carrier gas was newly grown up by the thickness of 3nm in 750 degrees C.
[0044] GaN of undoping which does not illustrate the carrier gas for TMI succeedingly while a stop and the carrier gas for TMG are turned to 1050 degrees C with a sink and carry out a temperature up for substrate 1 temperature was grown up by the thickness of 4nm after growing up a luminous layer 4. When substrate 1 temperature amounted to 1050 degrees C, p mold cladding layer 5 which newly consists the nitrogen gas as main carrier gas, hydrogen gas, the

carrier gas for TMA, and the carrier gas containing Cp2Mg for Cp2Mg of aluminum0.15Ga0.85N which made Mg dope with a sink was grown up by the thickness of 0.1 micrometers.
[0045] p mold contact layer 6 which consists the carrier gas for TMG of a stop and GaN which made Mg dope succeedingly was grown up by the thickness of 0.1 micrometers after growing up p mold cladding layer 5.
[0046] The wafer with which even the room temperature degree was made to cool the temperature of a substrate 1 with a sink as it is, and the laminating of the gallium nitride system compound semiconductor was carried out [ammonia / a stop, the main carrier gas, and] on the substrate 1 in the carrier gas for TMG and the carrier gas for Cp2Mg was picked out from the coil after growing up p mold contact layer 6.
[0047] Thus, after carrying out the laminating of nickel (nickel) and the gold (Au) by the thickness of 5nm with vacuum deposition on the surface on the whole surface to the laminated structure of the buffer layer 2 and n mold contact layer 3 which consist of a formed gallium nitride system compound semiconductor, a luminous layer 4, p mold cladding layer 5, and p mold contact layer 6, respectively, the light transmission nature electrode 7 was formed by the photolithography method and the wet etching method.
[0048] The insulator layer 21 which consists of SiO2 with a heat CVD method is made to deposit by the thickness of 0.5 micrometers on the light transmission nature electrode 7 and exposed p mold contact layer 6. Then, by the photolithography method and the reactive-ion-etching method While forming two or more holes 12 and space 13 in the insulator layer 21 and forming two or more crevices 11 in the light transmission nature electrode 7, the mask which consists of an insulator layer 21 for exposing a part of surface of p mold contact layer 6 was formed. Here, it presupposed that it is circular and the hole 12 has been arranged in a grid pattern at intervals of 10 micrometers except for the field with a opening diameter of about 2 micrometers which forms the p lateral electrode 5 (pad electrode) behind.
[0049] By next, the reactive-ion-etching method using chlorine-based gas using the above-mentioned mask While removing p mold contact layer 6, p mold cladding layer 5, and a luminous layer 4 from the surface side of exposed p mold contact layer 6 in a depth of about 0.3 micrometers and exposing the surface of n mold contact layer 3 From the hole 12 formed in the insulator layer 21 on the light transmission nature electrode 7, the light transmission nature electrode 7, p mold contact layer 6, p mold cladding layer 5, and the luminous layer 4 were etched, and the crevice 11 of the depth which reaches n mold contact layer 3 was formed. The crevice 11 was formed as a cavity whose path of about 2 micrometers and a pars basilaris ossis occipitalis the aperture of a opening is about 1 micrometer.
[0050] Then, the insulator layer 21 was removed by the wet etching method, by vacuum deposition and the photolithography method, the field in which the crevice 11 on the surface of the light transmission nature electrode 7 is not formed, and on the surface of exposed n mold contact layer 3, the laminating of the titanium (Ti) of 0.1-micrometer thickness and the Au of 0.5-micrometer thickness was carried out, and the p lateral electrode 8 and the n lateral electrode 9 were once formed, respectively. Furthermore, the insulating film 10 which consists of SiO2 of 0.2-micrometer thickness which covers the surface of the light transmission nature electrode 7 and the inside of a crevice 11 by the heat CVD method and the photolithography method was formed.
[0051] Then, the rear face of the substrate 1 of sapphire was ground, it was made thin and the scribe separated into about 100 micrometers in the shape of a chip. After turning the electrode forming face side upward and pasting up this chip on a stem, the resin mold of the p lateral electrode 8 and the n lateral electrode 9 of a chip was connected and carried out to the electrode on a stem with the wire, respectively, and light emitting diode was produced.
[0052] When this light emitting diode was driven by 20mA forward current, light was emitted in blue with a peak wavelength of 470nm. The radiant power output at this time was 2.0mW, and forward direction operating voltage was 3.5V.
[0053] In addition, although the light transmission nature electrode 7 of a crevice 11 was removed by the reactive-ion-etching method at this example at the same production process as the laminated structure which consists of a gallium nitride system compound semiconductor

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when forming a crevice 11, the light transmission nature electrode 7 of a crevice 11 may be removed independently in advance. For example, when carrying out wet etching of the laminating of nickel and Au formed all over the wafer and carrying out patterning of the light transmission nature electrode 7, the light transmission nature electrode 7 of a crevice 11 can also be removed to coincidence.
[0054] Moreover, in this example, although the configuration of the opening of a crevice 11 was made circular, it is not limited to this and the configuration of arbitration can be taken in the range which does not have trouble in formation of a crevice 11.
[0055] (Example of a comparison) The gallium nitride system compound semiconductor light emitting device which does not form a crevice 11 for the comparison with the above-mentioned example was produced.
[0056] In the above-mentioned example, specifically by the were using light transmission nature electrode 7 by insulator layer 21, and using chlorine-based gas reactive-ion-etching method in a whole surface ****** condition, without forming a hole 12 in the insulator layer 21 on the light transmission nature electrode 7 From the surface side of exposed p mold contact layer 6, p mold contact layer 6, p mold cladding layer 5, and the luminous layer 4 were removed in a depth of about 0.3 micrometers, and the surface of n mold contact layer 3 was exposed. Others produced light emitting diode with the same procedure as an example. Although peak wavelength and forward direction operating voltage were the same as that of an example when this light emitting diode was driven by 20mA forward current, the radiant power output was as low as 1.2mW.
[0057]
[Effect of the Invention] by forming two or more crevices which become depressed from a light transmission nature electrode side in the contact layer in which a light transmission nature electrode is formed according to this invention as mentioned above, since the light which goes to a longitudinal direction among the light emitted from the luminous layer is taken out from a crevice in the light emitting device exterior, optical ejection effectiveness improves as a whole, and the luminous efficiency of a gallium nitride system compound semiconductor light emitting device can be boiled markedly, and can be raised.
[0058] Moreover, since crevice formation can be performed simple, without newly adding the production process for crevice formation by performing formation of a crevice at the same production process as the production process of etching for exposing the first conductivity-type contact layer, the manufacture method of the gallium nitride system compound semiconductor light emitting device which can raise luminous efficiency only by minute production process modification called modification of a mask pattern can be offered.

[Translation done.]

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] The drawing of longitudinal section showing the structure of the gallium nitride system compound semiconductor light emitting device concerning the gestalt of 1 operation of this invention
[Drawing 2] The plan of the gallium nitride system compound semiconductor light emitting device shown in drawing 1
[Drawing 3] The drawing of longitudinal section showing the manufacturing process of the gallium nitride system compound semiconductor light emitting device shown in drawing 1
[Drawing 4] The drawing of longitudinal section showing the manufacturing process of the gallium nitride system compound semiconductor light emitting device shown in drawing 1
[Drawing 5] The drawing of longitudinal section showing the manufacturing process of the gallium nitride system compound semiconductor light emitting device shown in drawing 1
[Description of Notations]
1 Substrate
2 Buffer Layer
3 N Mold Contact Layer
4 Luminous Layer
5 P Mold Cladding Layer
6 P Mold Contact Layer
7 Light Transmission Nature Electrode
8 P Lateral Electrode
9 N Lateral Electrode
10 Insulating Film
11 Crevice

[Translation done.]

* NOTICES *

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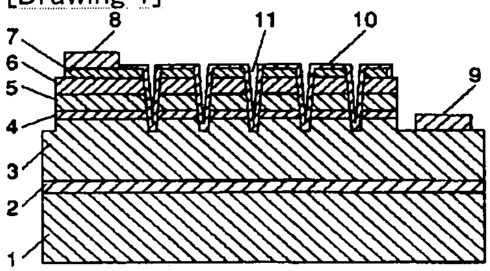
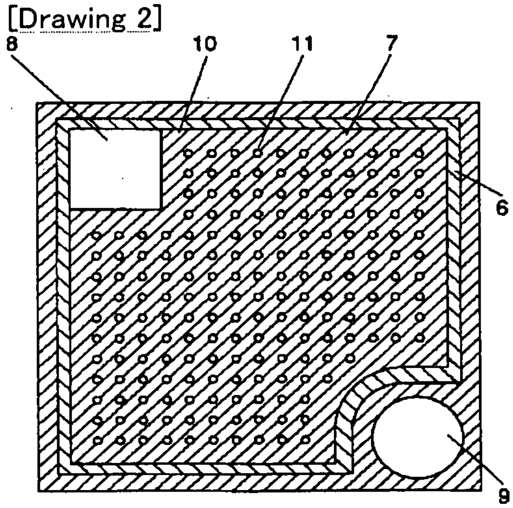
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

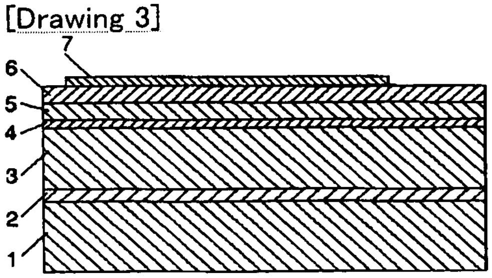
[Drawing 1]



[Drawing 2]



[Drawing 3]



[Drawing 4]

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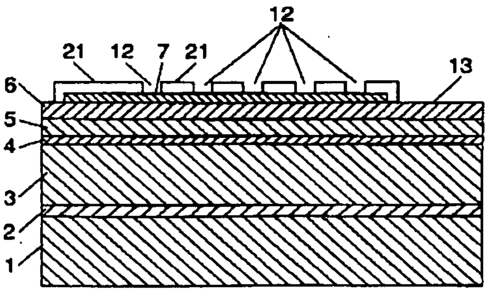
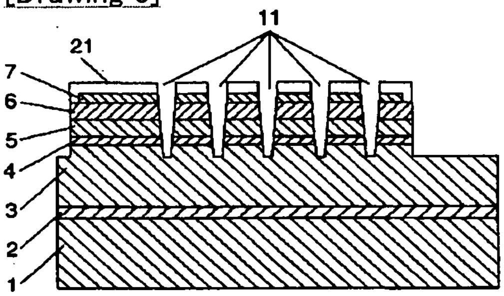


[Drawing 5]



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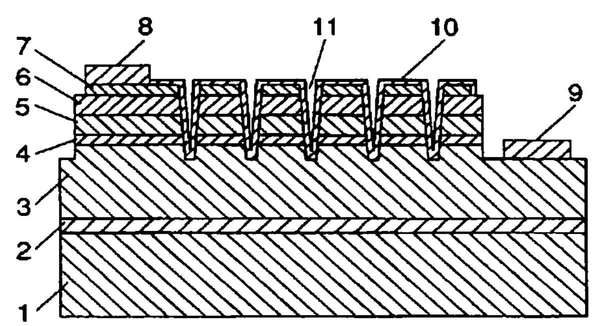
最終頁に続く

(54)【発明の名称】 窒化ガリウム系化合物半導体発光素子およびその製造方法

(57)【要約】
【課題】 光透過性電極を形成した面を主光取り出し面側とし、発光効率を向上させた窒化ガリウム系化合物半導体発光素子およびその製造方法を提供することを目的とする。
【解決手段】 基板１上にそれぞれ窒化ガリウム系化合物半導体からなるバッファ層２とｎ型コンタクト層３と発光層４とｐ型クラッド層５とｐ型コンタクト層６とが順に積層され、さらにｐ型コンタクト層６上に光透過性電極７が形成され、光透過性電極７上にはｐ側電極８が、ｎ型コンタクト層３上にはｎ側電極９がそれぞれ形成された窒化ガリウム系化合物半導体発光素子に対し、ｐ型コンタクト層６に光透過性電極７側から窪む凹部１１を複数個形成することにより、発光層４から発せられ、発光素子内部を横方向に伝播する光が凹部１１より発光素子外部へ取り出されやすくなり、全体として発光効率が改善される。



【特許請求の範囲】
【請求項１】窒化ガリウム系化合物半導体からなる第一導電型コンタクト層と発光層と第二導電型コンタクト層とが積層され、さらに前記第二導電型コンタクト層上に光透過性電極が形成される窒化ガリウム系化合物半導体発光素子であって、
前記第二導電型コンタクト層に前記光透過性電極側から窪む凹部が複数個形成されることを特徴とする窒化ガリウム系化合物半導体発光素子。
【請求項２】前記凹部は、前記発光層に達する深さまで形成されることを特徴とする請求項１記載の窒化ガリウム系化合物半導体発光素子。
【請求項３】前記凹部の内面が、絶縁性膜により覆われることを特徴とする請求項１または２記載の窒化ガリウム系化合物半導体発光素子。
【請求項４】窒化ガリウム系化合物半導体からなる第一導電型コンタクト層と発光層と第二導電型コンタクト層とを成長させる工程と、前記第二導電型コンタクト層上に光透過性電極を形成する工程と、前記第二導電型コンタクト層に前記光透過性電極側から窪む凹部を形成するための開口を有するパターーンを形成したマスクを前記光透過性電極上に形成する工程と、前記マスクを用いて前記第二導電型コンタクト層側から前記発光層に達する深さまでエッチングを行う工程とを含む窒化ガリウム系化合物半導体発光素子の製造方法。
【請求項５】窒化ガリウム系化合物半導体からなる第一導電型コンタクト層と発光層と第二導電型コンタクト層とを成長させる工程と、前記第一導電型コンタクト層の表面を露出させる工程と、この露出させた第一導電型コンタクト層上に電極を形成する工程とを含む窒化ガリウム系化合物半導体発光素子の製造方法であって、
さらに、前記第二導電型コンタクト層上に光透過性電極を形成する工程と、前記第二導電型コンタクト層に前記光透過性電極側から窪む凹部を形成するための開口を有するパターーンを形成したマスクを前記光透過性電極上に形成する工程と、前記マスクを用いて前記第二導電型コンタクト層側から前記発光層に達する深さまでエッチングを行う工程とを含み、
前記エッチングを行う工程は、前記第一導電型コンタクト層の表面を露出させる工程と同一工程で行うことを特徴とする窒化ガリウム系化合物半導体発光素子の製造方法。
【発明の詳細な説明】
【０００１】
【発明の属する技術分野】本発明は、発光ダイオード等の光デバイスに利用される窒化ガリウム系化合物半導体発光素子およびその製造方法に関する。
【０００２】
【従来の技術】窒化ガリウム系化合物半導体は、可視光発光デバイスや高温動作電子デバイス用の半導体材料として多用されており、青色や緑色の発光ダイオードの分野での実用化や青紫色のレーザダイオードの分野での展開が進んでいる。
【０００３】この窒化ガリウム系化合物半導体を用いた発光素子の製造においては、有機金属気相成長法によって窒化ガリウム系半導体薄膜結晶を成長させるのが近来では主流である。この方法は、窒化ガリウム系半導体としてのサファイアやＳｉＣ、ＧａＮ等からなる基板を設置した反応管内に、３族元素の原料ガスとして有機金属化合物ガス（トリメチルガリウム（以下、「ＴＭＧ」と称す）、トリメチルアルミニウム（以下、「ＴＭＡ」と称す）、トリメチルインジウム（以下、「ＴＭＩ」と称す）等）と、５族元素の原料ガスとしてアンモニアやヒドラジン等とを供給し、基板温度をおよそ７００℃～１１００℃の高温で保持して、基板上にｎ型層と発光層とｐ型層とを成長させてこれらを積層形成するというものである。ｎ型層の成長時にはｎ型不純物原料ガスとしてモノシラン（SiH_4）やゲルマン（GeH_4）等を、ｐ型層の成長時にはｐ型不純物原料ガスとしてビスシクロペンタジエニルマグネシウム（Cp_2Mg）等を３族元素の原料ガスと同時に流しながら成長させる。
【０００４】この成長形成の後、ｎ型層の表面およびｐ型層の表面にそれぞれｎ側電極およびｐ側電極を形成し、チップ状に分離することによって、発光素子を得ることができる。そして、これらの発光素子をリードフレーム等に固定し、最後にエポキシ樹脂等で封止することにより、発光ダイオードとして完成させる。
【０００５】最近の窒化ガリウム系化合物半導体発光素子においては、ｐ型層の表面からｐ型層、発光層およびｎ型層の一部をエッチングにより除去して露出させたｎ型層の表面にｎ側電極を、ｐ型層の表面にｐ側電極として発光層からの光を透過することができる程度の肉薄の光透過性電極をそれぞれ形成し、この光透過性電極の側を主光取り出し面側とする素子構造が主流である。このような構成によれば、素子の同一面側にｐ側電極及びｎ側電極を設ける場合においてもｐ側電極及びｎ側電極間における短絡を防止することができるとともに、素子サイズを小さくすることができる。
【０００６】しかし、上記のようにサファイア基板上に窒化ガリウム系化合物半導体を積層させた素子構造においては、次のような問題がある。すなわち、結晶成長用の基板と窒化ガリウム系化合物半導体との屈折率の違い、および窒化ガリウム系化合物半導体発光素子とそれを封止する樹脂等との屈折率の違いにより、窒化ガリウム系化合物半導体の発光がそれらの界面で多重反射されて干渉したり、反射光が窒化ガリウム系化合物半導体内部で吸収され発光を効率良く外部に取り出せないという問題がある。
【０００７】このような問題を解決するものとして、特開平６－２９１３６８号公報において、サファイア基板

上に窒化ガリウム系化合物半導体が積層されてなる発光素子において、前記窒化ガリウム系化合物半導体の最上層の表面が非鏡面とされていることを特徴とする窒化ガリウム系化合物半導体発光素子が提案されている。この発光素子によれば、サファイア基板と窒化ガリウム系化合物半導体層との界面で反射した光が非鏡面とされた最上層で散乱するため、窒化ガリウム系化合物半導体内部での多重反射が抑制され、光の干渉が少なくなり発光効率が向上するとされている。

【０００８】

【発明が解決しようとする課題】しかしながら、上記のように窒化ガリウム系化合物半導体の最上層を非鏡面とする構成においても、以下のような問題がある。すなわち、この最上層の側を発光素子の主光取り出し面側とする場合、この最上層の上に発光層からの光を透過させる程度に肉薄の光透過性電極を形成することとなるが、非鏡面の最上層に極薄の電極を膜厚均一に形成することは非常に困難となり、当該電極から窒化ガリウム系化合物半導体に均一に電流を供給することができず、かえって発光効率を低下させる原因となるという問題がある。

【０００９】本発明において解決すべき課題は、光透過性電極を形成した面を主光取り出し面側とし、発光効率を向上させた窒化ガリウム系化合物半導体発光素子およびその製造方法を提供することである。

【００１０】

【課題を解決するための手段】本発明の窒化ガリウム系化合物半導体発光素子は、光透過性電極が形成されるコンタクト層に光透過性電極側から窪む凹部が複数個形成されることを特徴とする。

【００１１】このような構成によれば、発光層から発せられ、発光素子内部をコンタクト層に平行な方向（横方向）に伝播する光が、凹部より発光素子の外部に取り出されやすくなる。すなわち、発光層からの光の取り出し効率が改善され、全体として発光効率を向上させることが可能となる。

【００１２】また、本発明の窒化ガリウム系化合物半導体発光素子の製造方法は、凹部の形成を第一導電型コンタクト層を露出させるためのエッチングの工程と同一工程で行うことを特徴とする。

【００１３】このような製造方法によれば、凹部形成のための工程を新たに付加することなく簡便に凹部形成を行うことができるため、マスクパターンの変更という微小な工程変更だけで発光効率を向上させることができる窒化ガリウム系化合物半導体発光素子の製造方法を提供することができる。

【００１４】

【発明の実施の形態】請求項１に記載の発明は、窒化ガリウム系化合物半導体からなる第一導電型コンタクト層と発光層と第二導電型コンタクト層とが積層され、さらに前記第二導電型コンタクト層上に光透過性電極が形成される窒化ガリウム系化合物半導体発光素子であって、前記第二導電型コンタクト層に前記光透過性電極側から窪む凹部が複数個形成されることを特徴とする窒化ガリウム系化合物半導体発光素子としたものである。これにより、発光層から発せられ、発光素子内部を横方向に伝播する光が、凹部より発光素子外部へ取り出されやすくなる。すなわち、発光素子外部への光の取り出し効率を改善することができる。

【００１５】請求項２に記載の発明は、前記凹部は、前記発光層に達する深さまで形成されることを特徴とする請求項１記載の窒化ガリウム系化合物半導体発光素子としたものである。これにより、ダブルヘテロ構造とした発光素子の光が比較的屈折率の小さい発光層を中心に伝播しやすいため、その発光層に達する深さまで形成された凹部より効率よく光を取り出すことができ、発光素子外部への光の取り出し効率をより高めることができる。

【００１６】請求項３に記載の発明は、前記凹部の内面が、絶縁性膜により覆われることを特徴とする請求項１または２記載の窒化ガリウム系化合物半導体発光素子としたものである。このような絶縁性膜を介することによって、窒化物ガリウム系化合物半導体の屈折率とこれを封止する樹脂等との屈折率との違いを緩和し、発光素子外部への光取り出し効率をさらに向上させることができる。また、凹部が第一導電型コンタクト層から第二導電型コンタクト層に渡って形成されている場合においては、これらの短絡を防止することができる。

【００１７】請求項４に記載の発明は、窒化ガリウム系化合物半導体からなる第一導電型コンタクト層と発光層と第二導電型コンタクト層とを成長させる工程と、前記第二導電型コンタクト層上に光透過性電極を形成する工程と、前記第二導電型コンタクト層に前記光透過性電極側から窪む凹部を形成するための開口を有するパターンを形成したマスクを前記光透過性電極上に形成する工程と、前記マスクを用いて前記第二導電型コンタクト層側から前記発光層に達する深さまでエッチングを行う工程とを含む窒化ガリウム系化合物半導体発光素子の製造方法としたものである。これにより、光透過性電極形成工程における凹部への電極材料の侵入による第一導電型コンタクト層と第二導電型コンタクト層との短絡を防止し、凹部に対応した孔を有する光透過性電極の形成の簡略化を行うことができる。

【００１８】請求項５に記載の発明は、窒化ガリウム系化合物半導体からなる第一導電型コンタクト層と発光層と第二導電型コンタクト層とを成長させる工程と、前記第一導電型コンタクト層の表面を露出させる工程と、この露出させた第一導電型コンタクト層上に電極を形成する工程とを含む窒化ガリウム系化合物半導体発光素子の製造方法であって、さらに、前記第二導電型コンタクト層上に光透過性電極を形成する工程と、前記第二導電型コンタクト層に前記光透過性電極側から窪む凹部を形成

するための開口を有するパターンを形成したマスクを前記光透過性電極上に形成する工程と、前記マスクを用いて前記第二導電型コンタクト層側から前記発光層に達する深さまでエッチングを行う工程とを含み、前記エッチングを行う工程は、前記第一導電型コンタクト層の表面を露出させる工程と同一工程で行うことを特徴とする窒化ガリウム系化合物半導体発光素子の製造方法としたものである。凹部の形成を第一導電型コンタクト層を露出させるためのエッチングの工程と同一工程で行うことにより、凹部形成を新たな工程を付加することなく、簡便に行うことができる。

【００１９】以下、本発明の実施の形態について、図面を参照しながら説明する。

【００２０】図１は本発明の一実施の形態に係る窒化ガリウム系化合物半導体発光素子の構造を示す縦断面図である。

【００２１】図１において、窒化ガリウム系化合物半導体発光素子は、サファイアからなる基板１上に、バッファ層２と、ＧａＮからなるｎ型コンタクト層３と、ＩｎＧａＮからなる発光層４と、ＡｌＧａＮからなるｐ型クラッド層５と、ＧａＮからなるｐ型コンタクト層６とが順に積層された構造である。なお、本実施の形態においては、ｎ型を第一導電型と、ｐ型を第二導電型としている。

【００２２】さらに、ｐ型コンタクト層６上のほぼ全面に光透過性電極７が形成され、光透過性電極７上にはワイヤボンディングのためのｐ側電極８が形成されている。一方、ｎ側電極９は、ｐ型コンタクト層６の表面からｎ型コンタクト層３に達する深さまでエッチングすることによって露出させたｎ型コンタクト層３の表面に形成されている。

【００２３】そして、ｐ型コンタクト層６には、光透過性電極７側から発光層４へ向かって窪む凹部１１が複数個形成されている。この凹部１１は、光透過性電極７を貫いて、ｐ型コンタクト層６からｎ型コンタクト層３に達する深さまで形成されている。さらに、凹部１１の内面と光透過性電極７の表面は、絶縁成膜１０によって覆われている。

【００２４】上記構成の窒化ガリウム系化合物半導体発光素子において、ｐ側電極８に正の電圧を、ｎ側電極９に負の電圧をそれぞれ印加すると、ｐ型コンタクト層６を介してｐ型クラッド層５からは正孔が、ｎ型クラッド層を兼用して形成されたｎ型コンタクト層３からは電子がそれぞれ発光層４に注入され、これらの正孔と電子の再結合により発光層４のバンドギャップに対応したエネルギーを有する光が発光層４より発せられる。

【００２５】凹部１１が形成されていない従来の発光素子構造の場合には、発光層４から発せられた光のうち上方へ向かう光は、光透過性電極７を介して発光素子外部へ取り出されるが、他の一部の光は発光素子内部を横方向へ伝播し窒化ガリウム系化合物半導体からなるｐ型クラッド層５およびｐ型コンタクト層６内部への吸収等により減衰した後、発光素子の側面から発光素子外部へ取り出されることとなる。

【００２６】これに対し、本実施の形態における発光素子構造の場合には、発光層４から発せられる光のうち横方向へ伝播する光が凹部１１より発光素子外部へ取り出されやすくなるとともに、光が発光素子内部を伝播する際の吸収等による減衰が低減されるため、全体として発光素子外部への光取り出し効率を向上させることができる。さらに、凹部１１の内面が、窒化ガリウム系化合物半導体の屈折率と、これを封止する封止樹脂または封止雰囲気の屈折率との間の屈折率を有する絶縁性膜１０により覆われることにより、窒化ガリウム系化合物半導体の屈折率とこれを封止する樹脂等との屈折率との違いが緩和され、発光素子外部への光取り出し効率をさらに向上させることが可能となる。

【００２７】また、凹部１１はｐ型コンタクト層６からｎ型コンタクト層３に達する深さとして、発光素子内部を横方向に伝播する光を凹部１１が形成されたコンタクト層全体から取り出すことができるようにしている。なお、この凹部１１の深さは発光素子内部を横方向へ伝播する光が到達して取り出される程度、すなわち発光層４に必ずしも達する必要はないが発光層４のすぐ近く、例えばｐ型クラッド層５に達する程度とすればよい。

【００２８】特に、この凹部１１の深さは、発光層４に達する深さとするのがより望ましい。例えば、本実施の形態のように、ＩｎＧａＮからなる発光層４をこれよりも屈折率の高いＧａＮやＡｌＧａＮからなるｎ型コンタクト層３およびｐ型クラッド層５で挟んでダブルヘテロ構造とする場合、光は比較的屈折率の小さい発光層４を中心に伝播しやすく、その発光層４に達する程度の深さとした場合には凹部１１より効率良く光を取り出すことが可能となるからである。

【００２９】さらに、凹部１１の内側面は、深さ方向（光透過性電極７側から発光層４側へ向かう方向）に進むにつれて細くなるようにテーパーが形成されるのが望ましい。これにより、凹部１１の側面から出射した光がこのテーパー付きの凹部１１の側壁に反射しながら凹部１１上方に導かれ、発光素子外部へと取り出されやすくなる。

【００３０】ここで、図２は図１に示す窒化ガリウム系化合物半導体発光素子の平面図である。図２に示すように、ｐ型コンタクト層６のほぼ全面に形成された光透過性電極７の領域内に、凹部１１が複数個形成されている。

【００３１】ｐ側電極８に正の電圧を、ｎ側電極９に負の電圧をそれぞれ印加すると、ｐ側電極８から注入された電流は光透過性電極７のほぼ全体に広がり、ｐ型コンタクト層６を介して発光層４へ注入される。これにより

発せられる発光層４からの光のうち、光透過性電極７の下方より発せられた光は光透過性電極７を介して発光素子外部へ取り出され、その一部は光透過性電極７を通過する際に一部吸収されて減衰する。一方、凹部１１が形成された領域には光透過性電極７は存在しないため、凹部１１より発光素子外部へ取り出される光は光透過性電極７によって吸収されることがなく、減衰せずに取り出される。

【００３２】凹部１１の開口の大きさは、凹部１１を形成する数にもよるが、開口を大きくするとそれに伴い光透過性電極７の面積が小さくなるため発光層４へ注入される電流密度が高くなる。一方、開口を小さくすると開口の形成が困難となるため、凹部１１の深さを制御しにくくなる。したがって、凹部１１の開口の大きさとその数には適当な範囲が存在するが、本発明者らの知見によれば、発光素子サイズを約３５０μｍ×３５０μｍとする場合、凹部１１の開口の大きさを０．５μｍφから５μｍφの範囲とし、その総面積が光透過性電極７の面積の０．１％から５０％の範囲となるように凹部１１の個数を調整するときに光取り出し効率の向上が顕著に認められている。

【００３３】次に、本実施の形態に係る窒化ガリウム系化合物半導体発光素子の製造工程について図面を参照しながら説明する。

【００３４】図３から図５は、図１に示す窒化ガリウム系化合物半導体素子の製造工程を示す縦断面図である。なお、本実施の形態においては、チップ状に分割された素子状態での製造工程を説明するが、実際の製造工程においては、図面に示す発光素子が二次元的に配列されたウエハ状態で各工程が実施される。

【００３５】図３に示すように、まず、サファイアからなる基板１上に有機金属気相成長法により窒化ガリウム系化合物半導体からなるバッファ層２とｎ型コンタクト層３と発光層４とｐ型クラッド層５とｐ型コンタクト層６とを順に成長させたウエハを準備した後、蒸着法とフォトリソグラフィ法を用いてｐ型コンタクト層６上に光透過性電極７を形成する。

【００３６】次に、図４に示すように、光透過性電極７と露出したｐ型コンタクト層６上に熱ＣＶＤ法によりSiO_2からなる絶縁膜２１を堆積させる。さらに、この絶縁膜２１にフォトリソグラフィ法を用い、光透過性電極７に複数の凹部１１を形成するための複数の孔１２およびｎ型コンタクト層３の表面の一部を露出させるための空間１３を形成し、次のエッチングのためのマスクとする。

【００３７】このマスクを用いて反応性イオンエッチング等により、図５に示すように、露出させたｐ型コンタクト層６の表面側からｎ型コンタクト層３に達するまでエッチングを行うことによって、ｎ型コンタクト層３の表面を露出させるとともに光透過性電極７の上に形成した孔１２からｎ型コンタクト層３に達する深さまで凹部１１を形成する。

【００３８】その後、光透過性電極７上の絶縁膜２１の一部をエッチングにより除去させ、露出させた光透過性電極７の表面上および露出させたｎ型コンタクト層３の表面上に、それぞれｐ側電極８およびｎ側電極９を蒸着法およびフォトリソグラフィ法により形成する。さらに、熱ＣＶＤ法とフォトリソグラフィ法により光透過性電極７と凹部１１の内面を被覆するSiO_2等からなる絶縁性膜１０を形成する。そして、ダイシングまたはスクライブ等によりチップ状に分離することにより、図１に示す窒化ガリウム系化合物発光素子が得られる。

【００３９】

【実施例】以下、本発明の窒化ガリウム系化合物半導体発光素子の製造方法の具体例について図面を参照しながら説明する。以下の実施例において、窒化ガリウム系化合物半導体の成長方法としては有機金属気相成長法を用いるが、成長方法はこれに限定されるものではなく、分子線エピタキシー法や有機金属分子線エピタキシー法等を用いることも可能である。

【００４０】（実施例）まず、表面が鏡面に仕上げられたサファイアの基板１を反応管内の基板ホルダーに載置した後、基板１の表面温度を１０００℃に１０分間保ち、水素ガスを流しながら基板を加熱することにより、基板１の表面に付着している有機物等の汚れや水分を取り除いた。

【００４１】次に、基板１の表面温度を５５０℃にまで降下させ、主キャリアガスとしての窒素ガスと、アンモニアと、ＴＭＡを含むＴＭＡ用のキャリアガスとを流しながら、ＡｌＮからなるバッファ層２を２５ｎｍの厚さで成長させた。

【００４２】その後、ＴＭＡのキャリアガスを止めて１０５０℃まで昇温させた後、主キャリアガスとしての窒素ガスと水素ガスとを流しながら、新たにＴＭＧを含むＴＭＧ用のキャリアガスと、SiH_4ガスとを流して、ＳｉをドープしたＧａＮからなるｎ型コンタクト層３を２μｍの厚さで成長させた。

【００４３】ｎ型コンタクト層３を成長後、ＴＭＧ用のキャリアガスとSiH_4ガスを止めて基板１温度を７５０℃にまで降下させ、７５０℃において、主キャリアガスとしての窒素ガスを流し、新たにＴＭＧ用のキャリアガスと、ＴＭＩを含むＴＭＩ用のキャリアガスとを流しながら、アンドープの$In_{0.2}Ga_{0.8}N$からなる単一量子井戸構造の発光層４を３ｎｍの厚さで成長させた。

【００４４】発光層４を成長後、ＴＭＩ用のキャリアガスを止め、ＴＭＧ用のキャリアガスを流しながら基板１温度を１０５０℃に向けて昇温させながら、引き続き図示しないアンドープのＧａＮを４ｎｍの厚さで成長させた。基板１温度が１０５０℃に達したら、新たに主キャリアガスとしての窒素ガスと水素ガスと、ＴＭＡ用のキ

ャリアガスと、Cp_2Mgを含むCp_2Mg用のキャリアガスとを流しながら、Mgをドープさせた$Al_{0.15}Ga_{0.85}N$からなるｐ型クラッド層５を０．１μmの厚さで成長させた。

【００４５】ｐ型クラッド層５を成長後、TMG用のキャリアガスを止め、引き続きMgをドープさせたGaNからなるｐ型コンタクト層６を０．１μmの厚さで成長させた。

【００４６】ｐ型コンタクト層６を成長後、TMG用のキャリアガスと、Cp_2Mg用のキャリアガスとを止め、主キャリアガスとアンモニアとをそのまま流しながら、基板１の温度を室温程度にまで冷却させて、基板１の上に窒化ガリウム系化合物半導体が積層されたウェハーを反応管から取り出した。

【００４７】このようにして形成した窒化ガリウム系化合物半導体からなるバッファ層２、ｎ型コンタクト層３、発光層４、ｐ型クラッド層５およびｐ型コンタクト層６の積層構造に対し、その表面上に蒸着法により、ニッケル（Ｎｉ）と金（Ａｕ）とをそれぞれ５ｎｍの厚さで全面に積層した後、フォトリソグラフィ法とウェットエッチング法により、光透過性電極７を形成した。

【００４８】この後、光透過性電極７と露出したｐ型コンタクト層６の上に熱ＣＶＤ法によりSiO_2からなる絶縁膜２１を０．５μmの厚さで堆積させ、フォトリソグラフィ法と反応性イオンエッチング法により、絶縁膜２１に複数の孔１２および空間１３を形成し、光透過性電極７に複数の凹部１１を形成するとともにｐ型コンタクト層６の表面の一部を露出させるための絶縁膜２１からなるマスクを形成した。ここで、孔１２は開口直径約２μmの円形とし、後にｐ側電極５（パッド電極）を形成する領域を除いて１０μmの間隔で碁盤の目状に配置した。

【００４９】次に、上記マスクを用いて、塩素系ガスを用いた反応性イオンエッチング法により、露出させたｐ型コンタクト層６の表面側からｐ型コンタクト層６とｐ型クラッド層５と発光層４を約０．３μmの深さで除去して、ｎ型コンタクト層３の表面を露出させるとともに、光透過性電極７上の絶縁膜２１に形成した孔１２から、光透過性電極７とｐ型コンタクト層６とｐ型クラッド層５と発光層４とをエッチングして、ｎ型コンタクト層３に達する深さの凹部１１を形成した。凹部１１は、開口の口径が約２μm、底部の径が約１μmの空洞として形成された。

【００５０】その後、一旦、絶縁膜２１をウェットエッチング法により除去して、蒸着法およびフォトリソグラフィ法により、光透過性電極７の表面上の凹部１１が形成されていない領域と、露出させたｎ型コンタクト層３の表面上とに、０．１μm厚のチタン（Ｔｉ）と０．５μm厚のＡｕとを積層して、それぞれｐ側電極８とｎ側電極９とを形成した。さらに、熱ＣＶＤ法とフォトリソグラフィ法により、光透過性電極７の表面と凹部１１の内面とを被覆する０．２μm厚のSiO_2からなる絶縁性膜１０を形成した。

【００５１】この後、サファイアの基板１の裏面を研磨して１００μm程度にまで薄くし、スクライブによりチップ状に分離した。このチップを電極形成面側を上向きにしてステムに接着した後、チップのｐ側電極８とｎ側電極９とをそれぞれステム上の電極にワイヤで結線し、樹脂モールドして発光ダイオードを作製した。

【００５２】この発光ダイオードを２０ｍＡの順方向電流で駆動したところ、ピーク波長４７０ｎｍの青色で発光した。このときの発光出力は２．０ｍＷであり、順方向動作電圧は３．５Ｖであった。

【００５３】なお、本実施例では、凹部１１を形成する際に、凹部１１の光透過性電極７を窒化ガリウム系化合物半導体からなる積層構造と同一工程で反応性イオンエッチング法で除去したが、凹部１１の光透過性電極７を事前に単独に除去しても構わない。例えば、ウェハー全面に形成したＮｉとＡｕの積層をウェットエッチングして光透過性電極７をパターニングするときに同時に凹部１１の光透過性電極７を除去することもできる。

【００５４】また、本実施例において、凹部１１の開口の形状を円形としたが、これに限定されるものではなく、凹部１１の形成に支障のない範囲で任意の形状をとることができる。

【００５５】（比較例）上記実施例との比較のために、凹部１１を形成しない窒化ガリウム系化合物半導体発光素子を作製した。

【００５６】具体的には、上記実施例において、光透過性電極７の上の絶縁膜２１に孔１２を形成せずに、光透過性電極７を絶縁膜２１で全面覆った状態で塩素系ガスを用いた反応性イオンエッチング法により、露出させたｐ型コンタクト層６の表面側から、ｐ型コンタクト層６とｐ型クラッド層５と発光層４とを約０．３μmの深さで除去して、ｎ型コンタクト層３の表面を露出させた。他は、実施例と同様の手順により発光ダイオードを作製した。この発光ダイオードを２０ｍＡの順方向電流で駆動したところ、ピーク波長と順方向動作電圧は実施例と同様であったが、発光出力は１．２ｍＷと低かった。

【００５７】

【発明の効果】以上のように本発明によれば、光透過性電極が形成されるコンタクト層に光透過性電極側から窪む凹部が複数個形成されることにより、発光層から発せられた光のうち横方向へ進む光が凹部から発光素子外部へ取り出されるため全体として光取り出し効率が向上し、窒化ガリウム系化合物半導体発光素子の発光効率を格段に向上させることができる。

【００５８】また、凹部の形成を第一導電型コンタクト層を露出させるためのエッチングの工程と同一工程で行うことにより、凹部形成のための工程を新たに付加する

ことなく簡便に凹部形成を行うことができるため、マスクパターンの変更という微小な工程変更だけで発光効率を向上させることができる窒化ガリウム系化合物半導体発光素子の製造方法を提供することができる。

【図面の簡単な説明】

【図１】本発明の一実施の形態に係る窒化ガリウム系化合物半導体発光素子の構造を示す縦断面図

【図２】図１に示す窒化ガリウム系化合物半導体発光素子の平面図

【図３】図１に示す窒化ガリウム系化合物半導体発光素子の製造工程を示す縦断面図

【図４】図１に示す窒化ガリウム系化合物半導体発光素子の製造工程を示す縦断面図

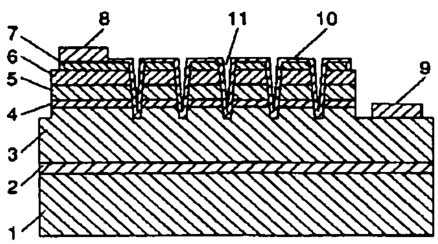
【図５】図１に示す窒化ガリウム系化合物半導体発光素＊

＊子の製造工程を示す縦断面図

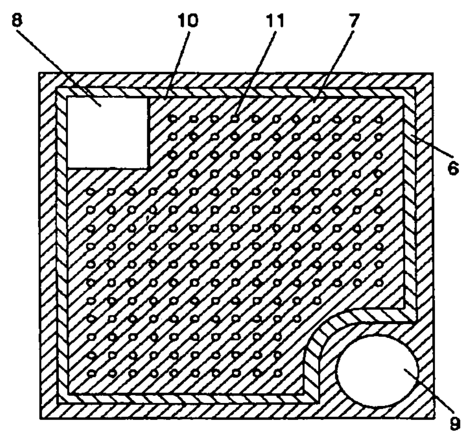
【符号の説明】

１　基板
２　バッファ層
３　ｎ型コンタクト層
４　発光層
５　ｐ型クラッド層
６　ｐ型コンタクト層
７　光透過性電極
８　ｐ側電極
９　ｎ側電極
１０　絶縁性膜
１１　凹部

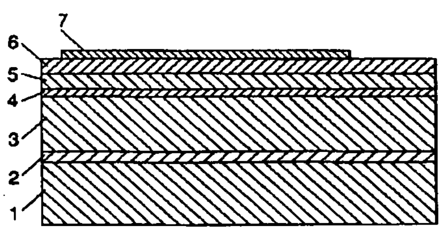
【図１】



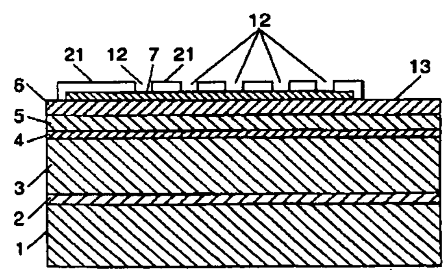
【図２】



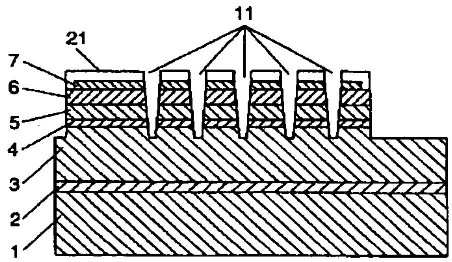
【図３】



【図４】



【図５】



フロントページの続き

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